Cohn (Ferd.)

BACTERIA:

The Smallest of Living Organisms.

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Translated by Charles S. Dolley.

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BY

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PREFACE BY TRANSLATOR.

Why scientific and medical books, above all others, should not be published in cheap editions in this country, as they are abroad, is a query that has occurred to me at various times since the beginning of my medical studies. With all our great publishing houses, I have yet to find the one that furnishes the student with scientific books at low prices. The popular demand is well supplied, but the German or French student has an advantage over the American, in that he has at his command low priced, usually paper cover, editions of all the best writings in medicine and science.

I have deemed no excuse necessary for offering to American students the present paper on a subject of so much importance, and by so eminent a writer, of whom Dr. Antoine Magnin says in his recent excellent work: "M. Cohn is the naturalist who, in our days, has occupied himself the most with the bacteria." Not having been accustomed to translate for publication, I would ask forbearance for the imperfections that may be found in the following pages. The figures in the appended lithographic plate were all drawn by Dr. Cohn for the *Microscopical Journal*, and it was preferred, on account of the greater number of forms depicted, to the one originally accompanying this article. In a few places, since writing which the author has had reason to change his views, I have endeavored to bring to bear the facts as known up to date, by means of notes, for which purpose I have had recourse principally to Dr. Sternberg's admirable translation of Magnin's work referred to above, and to which I would direct all who may desire to enter upon a more extended study of these "of all beings the most widely diffused."

C. S. D.

ROCHESTER, N. Y., *August* 9, 1881.

BACTERIA.

In the year 1875 science celebrated the second centennial of the discovery of a new world by Anton Leeuwenhoek, who while without classic education, was gifted with a strong desire for investigation ; the seventeenth century, the age of the greatest discoveries in natural science, animated him as well as many other gifted minds.

Leeuwenhoek had early in his youth left the merchant's shop in Amsterdam, which he had entered as an apprentice, and contented himself with the position of janitor of the court room in his native Delft, where he served thirty-nine years; but his spare time and his great mechanical talent he applied to the manufacture of magnifying glasses, with which he, commencing as an amateur, observed gnat wings, bee stings, butterfly scales and mosses.

But the previously unattained perfection of his microscope, and his clear and persevering gift of observation, soon revealed to him "deep secrets of nature,"* which he communicated to the Royal Society of Sciences in London in enthusiastic letters. In April, 1675, Leeuwenhoek placed beneath his microscope a glass tube full of standing rain water, and with astonished surprise he noticed in the water wonderful forms,—little bells which expanded and contracted themselves, with little globules which shot quickly here and there. At first he thought he saw the living atoms which, according to the philosophy of Democritus, composed all bodies, and from whose whirling motion his contemporary, Descartes, believed the world built itself anew. But Leeuwenhoek soon became satisfied that these were animalcules, invisible to the naked eye, but which in varied forms animated the drop of water. Other animal and plant forms were found later in great abundance, in infusions of pepper, hay and other

* LEEUWENHOEK, *Arcana naturæ detecta.*

animal and vegetal materials, and for that reason were named *Infusoria*. Exactly a century after Leeuwenhoek, Müller, an investigator in Denmark, having devoted twelve years of his life to the observation of these smallest of creatures, found, named and described about three hundred and eighty different forms in the fresh and salt waters of Copenhagen.*

In the next century the number of observers increased rapidly, who, with still more perfect instruments, sought to penetrate into the unseen world. Aside from the numerous animal race, a very peculiar microscopic flora was discovered, the appearance and development of which differed entirely from that of visible plants. If Leeuwenhoek was the Columbus of this new world, we may designate Ehrenberg the Humboldt of the same, for from the year 1829 up to the present day Ehrenberg has, with indefatigable diligence, thoroughly investigated these hidden provinces to the outermost boundaries; and not only described, delineated and classified the microscopical beings more thoroughly and more truly than his predecessors, but also unveiled the unsuspected importance which was due to creatures of the invisible world, in the entire natural arrangement, not only in the present, but in former geological ages.

Every one knows in how many relatively different sizes the life of the visible world embodies itself. The mites belong to the smallest creatures visible to the naked eye. They are found in numberless swarms in cheese, and in fruits rich in sugar. Their size compares to that of man about as a sparrow to the Strasburg Cathedral. A similar comparison may be made between the giant fir tree, and the moss which grows on its bark. Of the little animalcules that Leeuwenhoek discovered, he stated that their size compared with the mite as the bee with the horse. The more the microscope has been improved, and its magnifying power increased, the smaller have been the beings that became accessible to keen observation, since among the animals and plants of the unseen world, a difference in size is found, similar to that between the herring and the whale.

But the smaller the organism, the simpler appears to be its form, the more imperfect its life energy, and the lower its place in the rank of created beings. Among the animals of the micro-

* O. F. MÜLLER, *Virmium terrestrium et fluviatilium historia.*

scopic world, we find exceedingly few that possess the fullness of organs of an insect, a crab, or even of a worm: the true infusoria stand on the lowest step of the animal kingdom. Even so we find among microscopic plants not one that reaches the developed form of the blooming plant, or belongs to even the lowest class of the ferns; only the lowest plant forms, which we usually designate as algæ and fungi, form the forests and meadows of the invisible world.

But the more the inner formation of microscopic organisms is simplified, the fewer appear to be the characteristics which so easily separate plants and animals in the visible world. The infusoria are wanting in muscle and nerve, while vessels and breathing organs are very imperfectly developed. On the other hand microscopic plants show independent movement, and even organs of movement, such as we are only accustomed to find in animals. In the very lowest organisms animals and plants appear to run into each other, and the naturalist is in doubt to which of the two kingdoms he shall assign the subject of his investigations.

But the smallest, and at the same time the simplest and lowest of all living forms, we call *Bacteria.** They form the boundary line of life; beyond them life does not exist, so far at least as our present microscopic expedients reach; and these are not small. The strongest of our magnifying lenses, the immersion system of Hartnack, gives a magnifying power of from 3000 to 4000 diameters; and could we view a man under such a lens, he would appear as large as Mont Blanc, or even Chimborazo. But even under this colossal amplification the smallest bacteria do not appear larger than the points and commas of good print. Of their internal parts little or nothing is to be distinguished, and even their existence would for the most part remain hidden, did they not live in such gregarious masses.† These smallest

* From *βακτήριον*, a little staff or rod.

† "So long as the makers of microscopes do not place at our disposal much higher powers, and, as far as possible, without immersion, we will find ourselves, in the domain of the bacteria, in the situation of a traveler who wanders in an unknown country at the hour of twilight, at the moment when the light of day no longer suffices to enable him clearly to distinguish objects, and when he is conscious that, notwithstanding all his precautions, he is liable to lose his way."—COHN.

bacteria may be compared with man about as a grain of sand to Mont Blanc.

If it is important on their own account to learn to know these smallest and at the same time simplest of organisms, then will our interest be increased through the knowledge that just these little forms are of the very greatest moment; since they, with invisible, yet irresistible power, govern the most important processes of animate and inanimate nature; and even seize on the being of man secretly, but at the same time fatally.

The forms of the bacteria resemble sometimes balls or eggs, sometimes shorter or longer rods or fibres, and sometimes cork-screws or screws. The bodies consist of an almost colorless albuminous substance, in which numerous shining, fatty granules are embedded,* and which is inclosed in a thin membrane (cellulose), insoluble in caustic potash. According to their form, we can distinguish ball, rod, fibre and screw bacteria.

They are divided by scientists into genera and species. The author of this paper has in his new work recognized six genera, as follows:

1. *Micrococcus*,	ball or egg-shaped	bacteria,	figs. 1 to 7.
2. *Bacterium*,	short, rod-like	"	" 8 to 12.
3. *Bacillus*,	straight, fibre-like	"	" 14, 15.
4. *Vibrio*,	wavy, curl-like	"	" 16 to 18.
5. *Spirillum*,	short, screw-like	"	" 19 to 21.
6. *Spirochaete*,	long, flexible, spiral	"	" 22.

Nearly all bacteria possess two different modes of life, one of motion and another of rest. In certain conditions they are excessively mobile, and when they swarm in a drop of water, moving amongst each other in all directions, they present an attractive spectacle, similar to that of a swarm of gnats or an ant-hill. The bacteria swim rapidly forward, then, without turning about, retreat; or even describe circular lines. At one time they advance with a rocket-like spring, at another they

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* Some of these granules have recently been found to consist of crystalline sulphur (Cramer, Cohn). They have been observed in *Monas Okenii*, *Bacterium Sulphuratum*, and in the different species of *Beggiatoa*, which latter are found most abundantly in thermal sulphur waters, where they play a great *rôle* in the elimination of sulphur, and the disengagement of sulphuretted hydrogen (Magnin).

turn upon themselves like a top; or they remain motionless for a long time, in order as quick as lightning to be up and away. The longer, fibre-like bacteria bend their bodies in swimming, sometimes sluggishly, sometimes with address and agility, as if they were troubled to find their way through some impediment, like a fish that seeks its way among aquatic plants. Sometimes the little fibre stands still a long time, as though it would rest; then suddenly it begins to tremble, and swims back, in order soon to steer forward again. All these movements are accompanied by a rapid turning on the axis, like a screw moving in the screw nut; this becomes especially apparent if the little rods are bent, when they appear to be giddily whirling around. When the wavy formed vibrios and the screw formed spirilla turn themselves quickly on their axes, they give rise to a curious delusion, as if they possessed an eel-like motion, although they are in reality perfectly rigid. They often, meteor-like, dart here and there through the water, so that the observer is scarcely conscious of their presence, or they roll rapidly through the field of vision; sometimes they fasten themselves by one end, and move the other end in a circle exactly like a sling around the cord; soon after, one sees them winding slowly through the water.

Nearly all the older observers regarded bacteria as animals, since their movements were considered to be voluntary.* Certainly it is inner life energy which causes the movements of the

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* Bacteria were regarded as animals up to the time of Dujardin (1841), a kingdom—the *Protista*—midway between the animal and vegetable, being created by Haeckel for their especial benefit. Devaine (1859) was however among the first to show clearly their alliance with the algæ. Cohn holds them to belong to the algæ, although, from their want of chlorophyll, approaching the fungi. Magnin says: "If there are still some differences of opinion among naturalists as to the place of the bacteria among the cryptograms, there is but one opinion as to their vegetable nature. Sachs, however, solves the question by uniting the algæ and fungi in a single group, the *thallophytes*, in which he establishes two series exactly parallel—one comprising the forms with chlorophyll, the other the forms which are deprived of it."

To quote our author again: "The bacteria, then, resemble green plants, in that they assimilate nitrogen contained in their cells by taking it from ammonia compounds, which animals cannot do. They differ from green plants, in that they cannot draw their carbon from carbonic acid, and only assimilate organic substances containing carbon, above all the hydrates of carbon and their derivatives; and in this respect they resemble animals."

bacteria, and the power of movement is even more enigmatical, since no organs of motion are visible,* yet no doubt the appearance of volition is only a delusion. No mind energies, as they lie in our conception of volition, and which in fact govern the least of the actions of higher animals, are in play in the bacteria.

Exactly similar movements, as has been already remarked, are noticed in many microscopic plants, either continuing, as in the diatom and oscillaria, or transient during propagation, as the zoöspores or little seed-bodies of the algæ and fungi.

The collective development of the bacteria makes it in the highest degree probable that they belong to the vegetable kingdom, and in the nearest relation to the *Oscillariæ.* Bacteria also change from a condition of movement to one of rest, when they cannot be entirely distinguished from common plant cells. They swarm only where there is favorable temperature, plenty of nourishment, and the presence of oxygen ; under unfavorable conditions they are motionless. Certain kinds of spherical bacteria appear never to move.†.

Like all living organisms, bacteria are capable of propagating themselves. This propagation depends on bi-partition ("fission"). The bacterium grows till it has reached perhaps double its original size, then constricts itself in the middle like a figure eight, and breaks into two new individuals ; each of these in a short time divides again, and on account of the rapidity of this process we usually find them multiplying, either constricted in the middle, or hanging together in pairs. The warmer the air, the faster proceeds the division, and the stronger the multiplication ; in a lower temperature it becomes slower, and ceases

* Ehrenberg was the first to maintain that the motion of bacteria depended upon the presence of vibratile cilia (observed by him in *spirillum volutans*); "but, although the cilia, denied at first by most microscopists, have been seen since in nearly all the bacteria, recent researches permit us to say that cilia exist without doubt in all the true bacteria ; the botanists who have best studied them, M. Warming for example, recognize that it is scarcely probable that these organs are the cause of their movements, for 'one meets some examples in which the body remains motionless while the cilia are in violent agitation, and others in which the body moves, while the cilia remain inert, or dragging behind.' "—MAGNIN.

† *Micrococcus*, COHN.
Bacillus anthracis, COHN. *Bacteridie charbonnense*, DAVAINE.

entirely in the neighborhood of the freezing point. It well repays the trouble to make by computation an exhibition of the incredible masses to which these smallest of all organisms are capable of multiplying themselves. We know that bacteria divide themselves in the space of an hour into two parts, then again after another hour into four, after three hours into eight, etc. After twenty-four hours the number exceeds sixteen and a half millions (16,777,220); at the end of two days this bacterium will have multiplied to the incredible number of 281,500,000,000; at the end of three days it will have increased to forty-eight trillions; and after a week the number can only be expressed by figures of fifty-one places. In order to make this number comprehensible, we will reckon the mass and weight which may result from the multiplication of a single bacterium. A single individual of the most common species of rod bacteria (*Bacterium termo*) has the appearance of a short cylinder of a thousandth of a millimetre in diameter, and perhaps one five-hundredth of a millimetre in length. Let us now think of a cube, the side measuring a millimetre (cubic millimetre), six hundred and thirty-three millions of rod bacteria will completely fill this cavity without leaving any empty space. The fortieth part of a cubic millimetre would perhaps contain the bacteria that proceed from one single little rod in twenty-four hours; but at the end of the following day the bacteria would fill a space equal to 442,570 such cubes, or what is the same, perhaps, one-half a litre, or forty-four and a half cubic centimetres. Take the space which is occupied by the seas of this world, about two-thirds of the terrestrial surface, say with a mean depth of a mile, the collective contents of which would be nine hundred and twenty-nine millions of cubic miles; by continual progression of multiplication the bacteria which spring from one germ would in less than five days fill the whole world's seas completely full; the number can only be expressed by figures of thirty-seven places. Still more surprising are the proportional weights. If we call the specific weight of one bacterium equal to that of water, which cannot be far from the truth, it appears from the above mentioned measure that a single little rod will weigh 0.000,000,001,571 milligrammes, or that six hundred and thirty-six milliards of bacteria would weigh one gramme, or six hundred and thirty-six thousand milliards a kilogramme; after twenty-

four hours the weight of the bacteria amounts to about one fortieth of a milligramme; after forty-eight hours, nearly one pound (442 grammes); after three days it approximates a weight of nearly seven and one-half million kilogrammes, or 148,356 hundred weight.

We do not consider such computations idle play; they alone can make the immense work executed by the bacteria comprehensible to us. They also depend only on such hypotheses as nature herself presents to us; should, for example, the continuance of the process of fission be in truth somewhat longer than that stated by us, the numbers would agree in a few hours or days later. Certainly if in limited space this quantity is at no time reached, it perhaps does not signify that the power of multiplication in the bacteria falls below the calculation, but rather depends altogether on the limited nutrition. It is self-evident that bacteria do not generate the material which forms their bodies, but take it in from without as food, and therefore no more can be formed than there is food provided for. It follows that other animals and plants are assigned to the same food, and they on their side strive for existence. The fierce combat concerning life, according to the old usage of the extermination of the weaker, holds the increase of the bacteria, as of all other beings, in limitation; and it is only where they hold the upper hand that they are able to keep off the rivals which at the same time are their deadly enemies. A compressed yeast factory gives a plain example of the colossal proportions in which these little microscopic organisms can increase if abundance of nourishment is given them, and they are carefully protected from the opposition of other beings. The yeast fungus exceeds the rod bacteria in mass and weight probably one hundred and sixty fold.* The weight of a yeast cell is also about 0,000,000,25 milligrammes, or forty millions of yeast cells weigh one kilogramme. If they are in great vats filled with suitable food, and are allowed to remain undisturbed, inside of twenty-four hours over one hundred weight of yeast is generated.

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* I accept a yeast cell as a spherule whose diameter is 0.008 of a millimetre, and whose contents is 0.000,000,25 mm. In the compressed yeast factory of Giesmannsdorf, near Neisse, 100 centimetres of yeast consists of 75 % of water and 25 % of yeast fungus.

Probably there are more than fifty milliards of cells which form such a mass in the course of one day from one single grain.

We as yet know of no other mode of increase in the bacteria beside bi-partition. Generation of eggs and spores, as is found of all other animals and plants, has not yet been observed in these simplest forms.* After division the halves of the bacteria separate, and wander about as independent organisms, or remain connected chain-like, and form longer or shorter threads; in other cases whole generations remain congregated in colonies, united in nests or balls, or collected together in heaps, which appear to the naked eye as colorless or perhaps colored gelatinous or slimy masses,† as little white flakes or threads swimming in the water, or settle as flakes to the bottom of the fluid.

Bacteria belong to the most wide-spread of organisms; we may say they are omnipresent; they never fail either in air or water; they attach themselves to the surface of all firm bodies, but develop in masses only where decomposition, corruption, fermentation or putrefaction are present. If we place a piece of flesh, a pea or other animal or vegetable material in water, it will become, earlier or later, thick, and then milky. It loses

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* Since writing the above the author has satisfied himself not only of the existence of spores, but of veritable sporangia, and has by experiment found that the spores of *Bacillus* will for several days withstand a temperature of 80° (176° Fah.), still retaining the power of germination, while, along with Frisch, he has proven that gradual freezing does not destroy them, development having occurred after exposure to a temperature of —87° (—123° Fah.). He states that "reproduction by means of spores is only made under the influence of free access of air." Bacteria spores, besides their ability of resisting vicissitudes of temperature, will withstand complete dessication; and Magnin says: "These spores are the point of departure of epidemic foci, and their extreme lightness explains how readily they are disseminated by the wind. It has been shown from the experiments of Cohn and Miguel that the atmosphere contains very few adult bacteria; while Cohn again proves that these germs are of so small a diameter that they pass through all filters."

† "Cohn explains the origin of the gelatinous substance in which the bacteria are included as being produced by a thickening or jellification of the cell membrane; but a more plausible view is that it is produced by a secretion from their protoplasm. It is commonly the spherical bacteria (*Micrococcus*) and the microbacteria (*Bacterium*) which are found in this state. The bacteria are of course motionless in the *Zoöglœa* on account of the intermediary glairy substance."—MAGNIN.

The filliform bacteria and the spirilla, according to Cohn, are never found in gelatinous masses, but may be found in active swarms.

its transparency, because the bacteria completely fill the water; at the same time the putrefaction increases, under the development of different, and for the most part bad smelling chemical combinations. After a time the thickness disappears, and the water becomes clear and odorless, the organic material is consumed by the bacteria; these now cease to divide themselves further, and heap themselves on the bottom without motion as white sediment. If a new supply of nutritive material be added to the fluid, putrefaction and the multiplication of bacteria which are not dead, but in a state of temporary repose, are seen to begin anew.

They also multiply without water in moist air wherever they can find decaying matter. They cover cheese, cooked potatoes and other foods in damp closets with a slimy, colorless or colored coating, which even with the naked eye is easily distinguished from the snow white web-like mould fungus, sprinkled with blue white spore powder. A great part of the whitish slime that collects on the teeth is composed of bacteria (*Vibrio rugula*).

But how is it now that bacteria always develop in impure materials? In what relation do they stand to putrefaction? To these questions different answers are given.

One says: In the bodies of all living animals and plants the chemical elements are united in a peculiar combination called organic combination. Death loosens the bond by means of which the vital power of the elements was held. This leaves them to the free play of their attractions, and it follows that they rearrange themselves into new and more simple combination, the oxygen at the same time seeking to unite itself with the air, to which certain materials of the dead body have a close affinity. So results separation, disorganization, and new formation, through which the form and organization of the dead body becomes entirely destroyed. It is this process that we designate putrefaction and decay. It is a purely chemical process, comparable to combustion, effervescence, or the rust of metals. Bacteria find abundant nourishment in the combinations formed by putrefaction, while they can not be nourished on living bodies; no wonder then if their germ, if it find access only singly, increases so extraordinarily by putrefaction.

If this conception be true, bacteria are only chance accom-

paniers of decay, and the putrefaction of dead bodies must take place under special conditions, therefore, even if bacteria are kept away.

These conditions are not easily obtained if we wish to try experiments in order to prove the truth of this supposition. If for example we place a piece or some of the juice of an animal or plant, flesh, blood, urine, leaves, fruit or seeds in a small glass flask, it is most probable that a few of the extraordinarily wide spread bacteria would be placed in with it, and this supposition becomes almost a certainty if we add any water to the flask. It requires but a simple means to banish all the bacteria from the flask by cooking the same for a long time. Bacteria withstand boiling heat as little as other plants and animals; recent experiments have even shown that bacteria are killed by a temperature of 60° C., only the temperature must continue long enough to make sure that the whole mass has been penetrated, and not a single bacterium has escaped destruction. Decay is not removed by cooking alone; experience teaches that cooked flesh, eggs, milk, etc., take a much longer time, but finally decay as well as well as raw.

If one kills the bacteria already in the flask by means of heat, he must take care that no new germs enter from the air. For this purpose the Italian Abbot Spalanzani, an observer of nature in the last century, celebrated for his shrewd experiments, melted the neck of the little flask together during the cooking; the result was that the animal and plant material enclosed in the flask remained for all time unchanged, without putrefaction.

The French Count Appert used this method in the commencement of our century, in order to protect meat, vegetables, and other foods, by enclosing them in a metal box furnished with a small opening, then cooked them in a water-bath a couple of hours, and during the cooking soldered the opening; every housewife knows that food will keep for years in metal boxes without spoiling. Certain industries employ this method in preserving food in quantities; we indeed receive beef from Australia, and mutton from America, which is perhaps years old, but which when used is as if fresh.

The assertion has been made that the materials enclosed in the glass flask of Spalanzani, and the metal box of Appert, remained fresh not because there were no bacteria in them, but rather be-

cause there was no oxygen present; for it is certain that, by cooking, the air is expelled, and that the entrance of new oxygen through the soldering is impossible. In order to refute this objection, we must allow air free from bacteria to enter the hermetically sealed vessel. To accomplish this, Dr. Schwann in 1837 so modified the experiment of Spalanzani, that he did not melt the neck of the flask until after air had been blown in through a red-hot tube. By this process certainly all the living germs were destroyed.

Schröder and Dusch gave in 1854 a more convenient method; they stopped the neck of the little flask with cleansed cotton. After cooking, as the air penetrated into the flask by the cooling of the same, all the germs were retained between the fibres of the cotton, as in a filter.

Finally, in 1863, Pasteur thought of a more simple method. He drew the neck of the flask out, and bent it down horse-shoe shape without melting it; the germs contained in the air, which following gravitation, usually settle down in open vessels, could no more obtain entrance into the flask.

The result of these methods was always the same; the materials enclosed in the little flasks never fell into putrefaction; although there was no lack of air, only the bacteria found no entrance. From this and many similar experiments it may be concluded, with the greatest certainty, that where all other conditions for putrefaction are given, this still does not take place if no bacteria are present. On the contrary, putrefaction begins the moment that bacteria are intentionally or unintentionally added, should this be in the least number. Putrefaction goes on in the same measure in which the bacteria increase; all circumstances which favor the increase of the bacteria accelerate putrefaction; all circumstances which hinder their development delay putrefaction; and all means which destroy bacteria remove putrefaction. On the other hand the multiplication of bacteria ceases as soon as the substances capable of producing putrefaction are destroyed.

Therefore bacteria are not the chance companions, but rather the cause of putrefaction. *Putrefaction is a chemical process, excited by bacteria.* Death does not, as is generally supposed, cause putrefaction, but rather it is caused by the life of these invisible organisms.

It appears almost self-evident that every body from which life has departed submits to corruption ; and still this is known that without the life energy of bacteria all bodies after death would retain their form and combination as well as the Egyptian mummies, or the giants sunk in the Danish moors, or the mammoth and rhinoceros corpses which have remained frozen in the Siberian ice for unnumbered thousands of years, and which still retain their skin and hair uninjured. But as soon as the ice melts these last remains of an extinct animal world sink in a few days to corruption. The cause of this is easily comprehended : the life energy of the bacteria is suspended in the neighbourhood of the freezing point, while they, in a somewhat higher temperature, immediately multiply and excite putrefaction. In the bog, and in mummies, it is the chemical mixture which hinders the development of the bacteria. When a little piece of flesh or of plant material has remained unchanged for years in a little flask arranged after the method of Spalanzani, Schröder, Dusch, or Pasteur, one requires to add to it only a single drop of water containing bacteria in order immediately to usher in putrefaction.

The whole arrangement of nature is based on this, that the body in which life has been extinguished succumbs to dissolution, in order that its material may become again serviceable to new life. If the amount of material which can be moulded into living beings is limited on the earth, the same particles of material must ever be converted from dead into living bodies in an eternal circle ; if the wandering of the soul be a myth, the wandering of matter is a scientific fact. If there were no bacteria, the material embodied in animals and plants of one generation would after their decease remain bound, as are the chemical combinations in the rocks ; new life could not develop, because there would be a lack of body material. Since bacteria cause the dead body to come to the earth in rapid putrefaction, they alone cause the springing forth of new life, and therefore make the continuance of living creatures possible. The wonderful fact that putrefaction is a work performed by bacteria does not stand alone ; there is an entire series of chemical changes which are produced by bacteria and similar microscopic forms. These processes are usually designated as fermentation phenomena, and the organisms which cause the same as fermentation

fungi; among the bacteria the one that has been designated by investigators as *Bacterium termo* is the ferment of putrefaction.

That ferment which has been longest known, and most closely observed, is the alcohol ferment (*Saccharomyces cerevisiae*). Its little oval globules were first observed by Leeuwenhoek in beer, but in 1837 were known by Cognaird Latour, and about the same time by Schwann, as the cause of the ferment which changed sugar into carbonic acid and alcohol, while a small quantity of glycerine and succinic acid were formed. For the closest observations concerning the relation of yeast fungus to alcohol fermentation, we are indebted to Pasteur, from whose fame as the most ingenious and exact of modern French observers, we will not detract, even if he has not held himself aloof from the want of taste which would carry the bitterness of national passion into the neutral field of science. Pasteur showed that yeast fungus was composed of the same material as all other plants—of carbon, oxygen, hydrogen and nitrogen, and a number of minerals, among which potash and phosphoric acid are the most important. If the yeast plant grow, all these materials must be received as food, and applied by its life energy to the building of its cells. Yeast fungus does not find the whole of its nourishment in clear sugar, but as well in the pressed out juice of grapes, in beer wort and other fermentables; it multiplies itself only where it finds these. Oxygen and hydrogen are given to it in water; mineral materials which are identified later in the yeast ashes must also be present in solution. It was formerly thought that the yeast plant could only take up nitrogen from albuminous compounds, which are never wanting in juice of grapes and beer wort. Pasteur showed that the need of nitrogen can be satisfied through the taking in of ammonia, which consists of nitrogen and hydrogen. Finally, the yeast plant receives its carbon directly and exclusively from the sugar; probably the albumen which is present in the cell is formed by a combination of the sugar with the ammonia. Now, since the yeast plant needs the sugar in order to form, nourish and multiply its particular cells, it causes a dissolution of the sugar, and a new arrangement of its finest particles; this gives rise to the change, which has been designated alcohol fermentation. If the fermentation is over, the sugar has also disappeared, and the yeast plant can no more multiply; it settles itself in the bottom

of the fluid as dregs, or is thrown out by the violent escaping of carbonic acid, as foam or yeast, on the top.

Other fermentations are caused by bacteria, or by microscopical organisms which are related to bacteria only as they multiply themselves through division or parting of their cells, and on that account are united with bacteria in the class *Schizomycetes*. If beer or wine, through time or exposure to the air, becomes sour, acetic acid is formed: it is through bacteria,* which are united in long chains, or bound together in a slimy veil, that the alcohol of spirituous liquors becomes changed to acetic acid. Pasteur has shown that all diseases of wine are caused by microscopic ferment fungi, whose germs get into the fluid during the wine making, and there multiply themselves more or less rapidly. To him belongs the credit of at the same time turning this discovery to the practical account of the wine makers. When the wine is heated in the flasks to from 50° to 70° C., not only the acetic ferment, but also the schizomycetes are killed which make the wine mouldy, slimy or bitter—the wine becomes lasting, can be decanted, and increases in fire, bouquet and value.

When sweet milk becomes sour, it rests on this, that the sugar of milk is changed into lactic acid. Here is also a ferment fungus from the class of the bacteria, as Pasteur has proved.† When the milk is cooked, the lactic acid ferment is killed, and if the entrance of new germs is hindered, the milk will remain sweet through unlimited time. The same lactic acid ferment

* *Mycoderma aceti*, Pasteur.

"These little beings reproduce themselves with such rapidity that by placing an imperceptible germ upon the surface of a liquid contained in a vat having a surface of one square metre, we may see it covered in from twenty-four to forty-eight hours with a uniform velvety veil" (Duclaux). This veil is the so-called *mother of vinegar*. The *mycoderma aceti* must be distinguished from the *mycoderma vini*, which, while it develops in similar situations, is a species of *saccharomycete*, and is known commonly as *flowers of wine*. "In order that acetification may occur, the oxygen of the air is necessary. Once submerged, the *mycoderma aceti* develops, but no longer produces acetic acid (Magnin). However: "In effect, it is not then arrested in its work; and without changing form or mode of action, it carries the oxygen of the air to the acetic acid which it has produced, transforming it into carbonic acid and water. If we add some alcohol to the liquid, the phenomena change, the acid is respected, and the alcohol is transformed anew into acetic acid" (Duclaux).

† *Vibrio lactis*, Pasteur.

also plays a part in the preparation of saurkraut, cucumber pickles, &c. It develops in beet juice and in beer wort, and thus does much injury to the manufacturer.

Other ferment fungi cause other fermentations; one makes urine alkaline,* another changes tannin into gallic acid; still another plays a great *rôle* in butyric acid fermentation, and in the manufacture of cheese;† but especially interesting are the ferment fungi of the class of spherical bacteria which originate coloring matter.‡

It has long been a saying that suddenly, from time to time, a drop of blood would form on food, and especially on bread, and so increase that it would spread over wide surfaces. This was observed in ancient times, and it was held that it was a sign of threatened disaster, that it showed the anger of God, disclosed secret guilt, and called for bloody atonement; and history records numberless sacrifices which, till recent time, fell to the superstition, as often as this wonder of blood was seen on food, but especially if on the consecrated wafer.

With a century of enlightenment the blood wonder gradually ceased; but only within the last ten years do we know that the wonderful account had foundation in a fact of science. It was

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* *Micrococcus ureæ*, COHN, transforming urea into carbonate of ammonia.

† *Bacillus subtilis*, COHN (*Ferment butyrique*, PASTEUR).

"Butyric fermentation is in fact always preceded by a lactic transformation, and it is by an ulterior modification that the lactic acid produces the butyric acid. The reaction, represented by the phenomena, from a chemical point of view, is the following:

$$\underbrace{2\,C^3H^6O^3}_{\text{Lactic acid.}} = \underbrace{C^4H^8O^2}_{\text{Butyric acid.}} + 2\,CO^2 + H^4$$

This fermentation resembles putrefaction in a great many particulars. Indeed some authors include it under the same head" (MAGNIN).

‡ *Micrococcus chromogenes*, COHN.

"The pigmentary bacteria grow in the state of *Zoöglœa*, upon the surface of the substances which furnish them with nutriment. They are always alkaline; all are avid of oxygen; their morphological characters are identical, and one can only distinguish them by their different coloring properties.

According to Cohn they are veritable species; for, 1. Their pigments offer the greatest diversity as to chemical action, and by spectroscopic analysis, etc. 2. Each species cultivated in the most diverse media produces always the same coloring matter.

They are divided into two categories, according as the pigment is soluble or not in water" (MAGNIN).

Ehrenberg who first investigated this appearance of blood most carefully. It formed itself in moist air, on cooked, not on raw food; on potatoes, rice, paste; also on flesh, milk and white of egg, and of itself, without any one voluntarily causing it to be produced. At first it appeared as a very small rosy red or purple slimy drop, which grew to the size of a pin head, and appeared like fish spawn; then it flattened, ran together, and formed a thick bloody slime. If one spread out the red drop of gelatine-like substance on a fresh potato, it would multiply rapidly, and it has with ease been increased to so great a quantity that it could be used for coloring; unfortunately this coloring material is not durable, being soon destroyed by the light. Ehrenberg found in the red slime numberless little oval bodies, to which he gave the name of *Monas prodigiosus*; we dèsignate them better as red spherical bacteria (*Micrococcus prodigiosus*). They nourish themselves on the albumen contained in the food on the surface of which they develop, decompose the same, and generate, by a peculiar pigment fermentation, the red coloring matter, which, as Otto Erdman* and Schröter† have shown, possess a striking relation to that brilliant aniline color, which at the present time is of so much value to the coloring industry.

In historical interest, and in the mighty impression which it exercised on the myth-forming fancy of the people, the wonder blood stands alone; as a physical phenomenon it takes on a whole series of colors, which appear almost as a rule in moist places, on potatoes, cheese, cooked eggs and other foods; in appearance snow white, sulphur yellow, Spanish green, violet, blue or brown flecks, little drops or masses of mucus; all these colors, which are also related in part to aniline dyes, originate from spherical bacteria, which, under the microscope, can scarcely be distinguished from the *Micrococcus prodigiosus* of the wonder blood. If milk turns red or yellow of itself, or the pus from a wound takes a Spanish green color, the rod bacteria are designated as the originators of this coloring material.‡ The

* "Bildung von anilen Farben aus protein Körpern."—Journal für praktische Chemie, 1866.

† Schröter über einige durch Bacterien gebildete pigmente, in Cohn's Beitrage zur Biologie der Pflänzen. 1, 2. Heft 109–126.

‡ *Bacterium xanthinum*, SCHROETER. (*Vibrio synxanthus*, EHRB.)
Bacterium syncyanum, SCHROETER. (*Vibrio syncyanus*, EHRB.)
Bacterium æruginosum, SCHROETER.

litmus so much used by chemists is obtained, together with a few related pigments, from branching or crusty rock growing lichens by placing them in water as long as putrefaction continues, till the at first colorless extract takes on a beautiful purple, red or blue color wherever it comes in contact with the air. According to recent investigations, it is probable that litmus also is formed through the life energy of bacteria. They have succeeded by means of bacteria in producing, in a clear solution containing cream of tartar and acetate of ammonia, a coloring material exactly similar to litmus, which first colors the fluid a clear blue, becoming from day to day deeper and more beautiful. In other investgations the spherical bacteria appear to a certain extent as fabricators of Spanish green, yellow and red coloring materials, which they are able to produce from colorless chemical solutions.

At last, in the most recent times, an unexpected knowledge of the secret life energies of bacteria has been revealed, through which they rule with demoniacal power over the weal and woe, and even over the life and death of man.

Probably with the increase of commerce the visitation of that scourge of God, the epidemic, has grown more frequent, in the last ten years, on man and animals. It wanders with undetainable progress from city to city, from land to land, stopping at one place but a short time, then, as if exhausted, disappearing in order to carry on its work in a new locality, and usually after an interval of time, turning back again. Only too often the physician's skill and knowledge are exercised in vain to wrest the victim from the devastating power of these diseases, or to limit their course by rules of precaution. As various as are the different forms of disease, yet all epidemics, cholera, pestilence, typhus, diphtheria, variola, scarletina, hospital gangrene, epizoötic, and the like, have certain features in common. These diseases orignate nowhere of themselves, neither from internal nor external causes, but are introduced from another place where they have been prevalent, by means of a diseased person or through material which has been in contact with such: they spread only through contagion. When the infection has taken place, hours or even days may pass before the symptoms appear outwardly. After a certain time of incubation, the disease breaks out through a powerful disturbance of the normal action of all the organs,

from the brain to the digestive system; the diseased person appears as if he were under the influence of a poison which had penetrated into his blood; and as he himself is infected by the virus, he spreads it further by the breath, by the perspiration, by the excretions, even in the clothing or the washing. In many diseases the contagious material collects in a concentrated form in peculiar pustules or blisters, whose clear humor, in the slightest quantity, is sufficient to infect a sound person as soon as it has been received into his circulation, and to place him under the same appearances of disease as the originator of the poison. A breeze is sufficient to poison every open wound by the poison that adheres to the knife of the surgeon or anatomist. In anthrax it is positive that a fly may convey the poison from a diseased to a sound animal.

Scarcely had Leeuwenhoek made known his first observations upon the invisible creatures in rain water, when visionary physicians believed the premature hypothesis that the frightful enigma of epidemics was explained through the wafting of microscopical diseased germs. But until the most recent times, every endeavor, even with the help of the microscope, to find with certainty living organisms in the contagious material which originated with the disease, has been in vain. It were as easy to bring to sight the invisible arrow with which, according to the belief of the ancients, the far-darting Apollo in his anger prostrated men and cattle.

The first discovery of microscopical organisms in contagious diseases we owe to Davaine,* who in the year 1863 observed in the blood of a splenetic animal, a few hours before its death, numberless fine thread-like forms, which were almost double the length of blood corpuscles, which multiplied themselves by division, and could be distinguished from the ordinary fibre bacteria only through their lack of motion. Davaine on that account designated them *Bacteridia*. Man is subject to a contagious disease which is very nearly related to anthrax,† and in these cases the blood is filled with *Bacteridia*. Within about four years the number of epidemics in which bacteria appear has very

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* C. Davaine, Recherches sur les maladies charbonneuses, C. R. Ac. des Sc., t. LVII., p. 220, 351, 386, et t. LIX., p. 393.

† *Pustula maligna.*

much increased.* This, however, is not the place to discuss separate cases; we will, therefore, consider some of the more important according to the most recent observations.

Every one knows how mercilessly diphtheria destroys so many promising lives—an easily transmitted contagion, which usually firmly seats itself in the throat and air passages, generating there a membranous formation which threatens immediate death by suffocation. The microscope shows in all the organs of the diseased person numberless spherical bacteria, heaped together in thick masses, which pass through and besiege the tissues of the muscles, vessels and mucous membrane; everywhere congestion, inflammation, and a general blood poisoning, follow in consequence.

Blood poisoning through open wounds, which in war carries off more victims than the enemies' balls, and which, when it has gained a footing in a hospital, easily causes wounds to become fatal, is always accompanied by the multiplying of the spherical bacteria, which, sometimes singly, sometimes in wreath-like slimy heaps, settle themselves in the pus, or in the tissue of the scar, or are taken up in the blood and deposited in the different organs, where they cause inflammation, formation of abscesses, and through a consuming fever exhaust the most youthful vitality. In the clear lymph of cow or human pox spherical bacteria are also found in immense numbers, and undergoing rapid increase. In the rice water discharges of cholera, Kolb, as early as 1866, identified numberless bacteria bound together in gelatinous masses. Even the silk worm is subject to an epidemic in which bacteria appear.†

Does it then follow from the presence of bacteria that they truly have to do with epidemics? Is it not quite as probable that these microscopic forms are only chance and unessential accompaniers of disease? Bacteria certainly develop in every fermentation, and where there is any putrefaction, without exerting the least influence on health. As yet the diffused light of the most recent investigations is not clear enough to enable

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* We owe these facts to the observations of Keber, Hallier, Zürn, Klebs, Leyden, Recklinghausen, Jaffe, Waldeyer, Orth, Buhl, Hüter, Oertel, Traube and others.

† *Micrococcus bombycis*, COHN.

this dark province to be penetrated ; as yet the newly won ground is not firm enough to warrant the building of an unshaken theory ; still we already know that the bacteria of contagion are of a different kind from those which engender putrefaction ; these are distinguished from the latter under the microscope mostly through their form ; they exist under entirely different circumstances of life ; they often battle for existence with the bacteria of putrefaction, and are by them exterminated if they are conquered. Davaine found the bacteria of anthrax to disappear with the beginning of putrefaction, as early as forty-eight hours after the death of an animal ; and the rod bacteria at the same time to multiply beyond measure. But, while a drop of blood filled with anthrax bacteria will, when introduced into a sound animal, produce death in from twenty-four to thirty-six hours, the inoculation with putrefied blood containing no bacteria, is without effect. The bacteria of anthrax do not lose their vitality through dessication, therefore contagion may take effect through dried blood.

As is known, only fluid particles can pass through a compact filter, a clay cylinder, or a membrane ; little firm bodies, be they ever so small being retained. Chauveau and Klebs made use of these experiments, in order to show that in pyæmia, septicæmia, and variola, the contagion may not have its seat in the fluid portion of the pus or lymph, but in the microscopical spherical bacteria which develop in it. As they strained this same contagious material through a filter, they ascertained that the clear fluid which had passed through the filter had lost its contagious power, while the firm substances which remained on the filter were efficient.

All these facts make it in the highest degree probable that the already identified bacteria are in many diseases the conveyors and originators of infection, that they are the ferment of contagion. We have the firm conviction that to a more thorough and clearer knowledge of these facts will be joined the discovery of new methods by which to encounter the fearful enemy with better success than hitherto. The skill of the physician should be exerted to answer the following questions : In what way takes place, and in what manner can be hindered the transportation of microscopical organisms of fermentation ? and, Through what means can the multiplication of the same be arrested ? Especially

should their attention be turned to water, of which it is ascertained that when in a seemingly pure condition, it is an easy conveyance for the transmission of bacteria and other ferment organisms.

We have seen that bacteria multiply, under favorable circumstances, in all putrefaction and fermentation and in many diseases, as soon as their germ has once found access; that these smallest of organisms accomplish a vast work through the immense numbers in which they develope. But from whence is derived the first germ? With this question naturalists have busied themselves up to the most recent time, and their answers have been various.

One says: by putrefaction, the organic elements which had composed the body of the dead animal, form themselves by free creative power into independent beings, which differ entirely from those from which their material was produced, yet are in every case animated, and have the power of propagation; thus the albumin and little fat globules take the form of bacteria, perhaps also of yeast fungus and mould, or even of those little infusorial animals whose presence never fails in corruption. Indeed an especial name has been found for this mode of origin, *Generatio æquivoca*, or equivocal generation.

Another disputes the possibility of living beings, however small and simple, ever originating in any other way than from germinal matter which sprang from the same form of life; and insists that the belief in the equivocal origin of bacteria is the last remnant of an old superstition, which the light of science has not entirely banished. In ancient times it was thought that there originated from slime, serpents and frogs, which the sun brooded, that caterpillars generated from decayed leaves, vermin from filth, and worms from spoiled meat. Nowadays every child knows that all these things are fables; every housewife knows by experience that no maggots originate in meat, if the blow-fly is prevented by a wire screen from entering and depositing its eggs. They have learned through careful covering, to keep away the minute mould spores, which settle with other dust from the air, and which colonize on their preserved fruits; they know that trichina and tape-worm only originate from raw or half-cooked pork, in which these animals were already present in the embryonic stage. Even the farmer no longer

believes that the grain rust originates from chilling, but that it springs from germs which are scattered by the barberry bushes, or other fallen stalks, and that the blight may be arrested in wheat, if the seed is strained through sulphate of copper, in order to kill the spores which cling to it.

Concerning bacteria and their related fermentations, the above mentioned observations lead without doubt to the conclusion that they originate as little through equivocal generation as other living organisms; for when nitrogenous material from the animal and plant world is cooked in flasks, even at as low a temperature as 60° C., all the bacteria are killed, and if the entrance of new germs from outside is in every way hindered, and it were possible to keep the little flask forever, no bacteria would ever originate of themselves. On the contrary the entrance of a single germ is sufficient to cause multiplication, and with it putrefaction. If bacteria originate from putrid material through equivocal generation, putrefaction must appear before bacteria; but experience shows the contrary, that putrefaction is a consequence of the development of bacteria. Within the last few years a theory has caused some sensation by seeking to account for the origin of bacteria by saying that the ordinary mould-fungus will, under certain conditions bring forth moving germs of extraordinary minuteness; which germs are capable of developing into bacteria, into yeast, and finally again into mold. When bacteria are found in the blood or other organs in certain diseases, the authors of this theory are satisfied that the spores of common mould or blight fungus germinate in the human body; that these germs first swarm as bacteria, but under suitable culture may be nourished into different kinds of mould. However, unprejudiced research has not given the slightest proof that bacteria stand in any connection with the history of the development of yeast, blight, or mould fungus. They always originate, as far as we know at present, from germs of the same kind.

Through these facts we surely have a right to hope, that in the development of bacteria the key will be found to the origin of life in the world in general. If we could prove that through equivocal generation, one single organism, or living cell, shaped itself from unorganized and lifeless material, then could we conceive that the first created beings were in the beginning formed in a similar manner.

Now it is very certain that life had a beginning on the earth, but how did the first living beings originate? For this all analogy is wanting. According to our present knowledge life may be compared to the holy fire of Vesta, which is eternally maintained, through the kindling of the new brand from the old.

The famous physicist, Wyville Thompson, in an ingenious speech with which he opened the Natural Science Convention in Edinburg, drew the following conclusions: that life on this earth, not having originated of itself, must therefore have been conveyed to our world from another. We know that the numberless meteoric stones which have fallen to the earth, were once independent bodies or parts of such. In certain meteorites carbon, and certain combinations containing carbon, have been found, which points to organic formation. It is possible to think, that at some time a germ, with life and capacity for development, could have survived the glowing heat which generally accompanies the entrance of a new comer from space into our atmosphere, and that from such a germ all living beings might have descended. Thus, some time the commencement of life may have descended from Heaven upon this lifeless earth; as according to the myth, the living spark was brought down by Prometheus from Olympia.

The development history of the bacteria allows us to think of another origin of life on the earth. We have calculated the weight of one bacterium at 0.000,000,001,57 milligrammes; we know that these infinitely light little bodies are carried away through the evaporation of water, and float around in the air as little particles of sun dust, and with the dust again settle down; but they may be carried by the winds to unmeasurable distances, and also to extraordinary heights. It is more probable that these particles of fine dust are sometimes carried up by ascending currents of air, so far that they are deprived of the attraction of our planet, and reach space. The existence of a world dust is presumable from certain cosmical appearances of light. Space is exceedingly cold, yet experiments prove that even a chilling for many hours below —18° does not kill bacteria; they become stiff through cold, from which condition they revive when thawed, and under favorable circumstances again begin to multiply.* It is perhaps not impossible that an

* See previous note in regard to spores.

ascending particle of bacteria dust, which has floated for a long time in space, may reach the atmosphere of another world, and if it find there circumstances favorable to life, it multiplies. On the other hand, it is possible to think that a germ of *Bacterium*, or any other exceedingly small and simple form, from some other life-nourishing world, may have been moving about in space, and that such a germ, finally reaching our atmosphere, settled to the earth. As long as the primitive sea retained a temperature above 60°, the development of such a germ would have been impossible; but as soon as the cooling had fallen below this temperature, the stray germ of life must have found in the sea, richly saturated with salt, conditions for unlimited multiplication. We have calculated that the whole ocean might be filled with such organisms in a few days. From these first living germs, in which the pecularitities of the animal and vegetable kingdoms are not yet separated, the laws of development, the battle for existence, natural increase, geographical distribution, and many other known and unknown forces might have produced the different forms of the animal and plant world, which inhabited the earth in the past, as they do in the present. We know well that in the maintenance of such views,. we stray far from the boundaries of natural philosophy; but we find the naturalist, always remaining conscious of the limitations of his knowledge, admitting his ignorance with resignation, foiled in his experiments and observations; not always resisting the longing of Faust, "*Zu schauen alle Wirkungskraft und Samen*," but gladly giving himself up to the allurement of filling with some fantasy that blank at which modern investigation has failed.

THE END.

DESCRIPTION OF THE PLATE.

From "Microscopical Journal."

FIG. 1.—*Micrococcus prodigiosus* (*Monas prodigiosa*, Ehr.). Spherical bacteria of the red pigment, aggregated in pairs and in fours; the other pigment bacteria are not distinguishable with the microscope from this one.

FIG. 2.—*Micrococcus vaccinæ.* Spherical bacteria, from pock lymph in a state of growth, aggregated in short four to eight-jointed straight or bent chains, and forming also irregular cell-masses.

FIG. 3.—Zoöglœa-form of micrococcus, pellicles or mucous strata characterized by granule-like closely set spherules.

FIG. 4.—Rosary-chain (Torula-form) of *Micrococcus ureæ*, from the urine.

FIG. 5.—Rosary-chain and yeast-like cell masses from the white deposit of a solution of sugar of milk which had become sour.

FIG. 6.—*Saccharomyces glutinis* (*Cryptococcus glutinis*, Fersen.), a pollulating yeast which forms beautiful rose-colored patches on cooked potatoes.

FIG. 7.—Sarcina spec.* from the blood of a healthy man.** from the surface of a hen's egg grown over with *Micrococcus luteus*, forming yellow patches.

FIG. 8.—*Bacterium termo*, free motile form.

FIG. 9.—Zoöglœa form of *Bacterium termo.*

FIG. 10.—Bacterium-pellicle, formed by rod-shaped bacteria arranged one against the other in a linear fashion, from the surface of sour beer.

FIG. 11.—*Bacterium lineola*, free motile form.

FIG. 12.—Zoöglœa form of *B. lineola.*

FIG. 13.—Motile filamentous bacteria, with a spherical or elliptical highly refringent "head," perhaps developed from gonidia.

FIG. 14.—*Bacillus subtilis*, short cylinders and longer, very flexible motile filaments, some of which are in process of division.

FIG. 15.—*Bacillus ulna*, single segments and longer threads, some breaking up into segments.

FIG. 16.—*Vibrio rugula*, single, or in process of division.

FIG. 17.—*Vibrio serpens*, longer or shorter threads, some dividing into bits, at * two threads entwined.

FIG. 18.—"Swarm" of *V. serpens*, the threads felted.

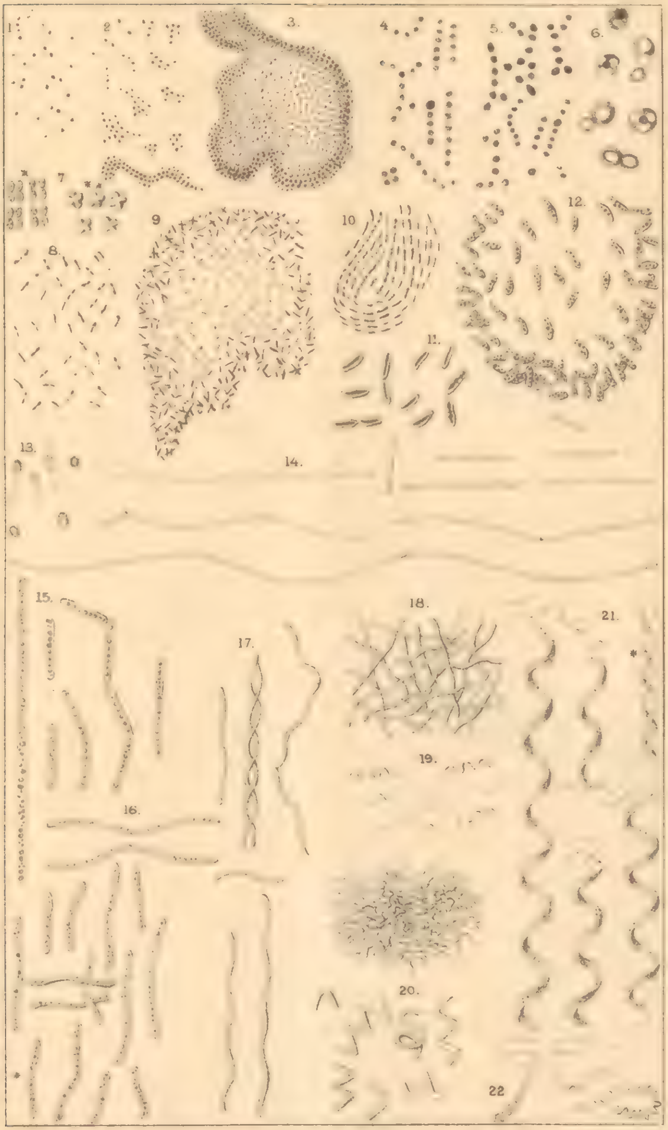
FIG. 19.—*Spirillum tenue*, single and felted into "swarms."

FIG. 20.—*Spirillum undula.*

FIG. 21.—*Spirillum volutans*,* two spirals twisted around one another.

FIG. 22.—*Spirochæte plicatilis.*

All the figures were drawn by Dr. Ferdinand Cohn with the immersion lens No. IX. of Hartnack Ocular III., representing a magnifying power of 650 diameters.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